REDUCTION OF SPRUCE AND FIR LITTER BY MINUTE ANIMALS

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The old idea of complete reduction of litter by inorganic chemical changes has proved erroneous. Various reducing agents, the best known being bacteria and fungi, subsequently have been studied. The following article describes how a few out of the host of species of minute animals of the forest floor contribute to the reducing process.

TO REPRODUCE themselves, forests are largely dependent upon seedlings. Spruce seedlings cannot grow and thrive if soil water is not constantly available within reach of the seedling's one or two-inch root system. Soil water may be isolated from the roots of young seedlings by a deep litter layer. Thus it is imperative to control the depth of litter accumulation. This can be done by encouraging decay of the litter. Spruce litter is reduced by the action of fungi, animals, and possibly bacteria.

Since reduction by animals can be controlled at least to the extent of introducing them in woodlands where they have been exterminated by fire, an attempt was made to determine what species of animals function as spruce litter reducers. As far as is known animals do not eat dry and seasoned spruce and fir needles. After fungi have softened and somewhat predigested the needles, animals are able to operate upon them. Two types of feeders may be recognized: *endophages* which eat the needles from the inside, and *ectophages* which eat the needles from the outside, much as we eat up a loaf of bread, or mice nibble into it. Since nothing definite is known of the ectophages, the present account will be limited to the endophages.

These studies were carried out at the Gale River Experimental Forest in northern New Hampshire. The litter examined was taken from a tract of undisturbed spruce flat type with yellow birch intermixed (*4*). There is no evidence that this tract has been burned over, at least for hundreds of years; the fauna has had ample time to become stabilized. In such a tract the humus forms a layer seven to occasionally fifteen inches deep. This is overlain by a layer of dry and of decaying spruce and fir needles about one inch deep. It is in this relatively shallow upper layer that the spruce and fir needles are reduced to faeces which form the bulk of the humus layer.

When spruce and fir leaves fall to the ground they are very quickly attacked by various fungi which break down the contents and structure of the needles. The most conspicuous of these

fungi, which seems to be *Lophodermium piceae* (Fückel) Höhnel[1] (*1*), reduces the internal structure of the leaf to a remarkable degree, leaving but a few filaments of tissue. It is also notable in that it operates on an even front forming a conspicuous black wall which extends as a definite flat barrier across the entire width and height of the leaf. This black transverse wall, one at each end of the disintegrating area, is noticeable on the outside of the leaf. Such a condition is accompanied on the surface of the leaf by a black, carbonaceous, oval pustule of considerable size, which splits open lengthwise. Animals living in such a leaf never break through the black wall and are never found between the walls.

A type of reduction common to fir needles leaves them very watery and thin, so that in a digested leaf the midrib and the lateral pitch rods stand high above the intervening tissues, like the bones of an emaciated animal.

As soon as the needles have been partly softened by fungi the animals are able to insert their ovipositors and lay their eggs which soon hatch into larvae. The larvae of at least four minute animals thus begin life within the walls of these small resinous needles; three are mites and one is a midge (Sciara). The mite larvae are short, white, and six legged. The midge larvae are long, cigar-shaped, and without legs.

As the mite larvae eat the palisade tissue immediately about them, they advance into the cleared area and deposit their oval, brown faeces in a pile behind them. When the larva is fat and stout it stops feeding to moult and thus acquires a much larger skin and a fourth pair of legs. It is then known as nymph I. Its cast suit lies behind it and soon becomes unrecognizably crumpled among the ever increasing pile of oval faeces. Only the mandibles and maxillae which are very heavily sclerotized, remain unchanged to mark the point of moult. After a period of feeding and fattening, nymph I moults to become the larger nymph II, which feeds and moults to become nymph III. At each moult certain additional structures, chiefly bristles are acquired. Thus it is possible to identify each nymphal stage by the bristles borne by the incumbent. By the time nymph III has reached the further end of the leaf it moults again to appear as a hard, brown, adult much resembling a minute beetle. The adult now cuts a hole in the epidermis, and steps out to search for a mate. As adults lay eggs all through the spring and summer, larvae, and nymphs in all three stages may be found throughout the growing season. This overlapping of life cycles insures more continuous and much greater needle reduction.

It is interesting to note that one species of mite (*Hoplophorella thoreaui* (*2*) (Fig. 1) is characteristic of spruce needles though also found in the short stout fir needles. Another species (*Phthiracarus boresetosus* (*2*) is characteristic of the flat fir needles. The egg is usually laid in the proximal end of the fir leaf, possibly through the attachment disc, and the mite eats its way down the ever broadening needle. The third species (*Adoristes ovatus ammonoosuci* (*3*) is found in both spruce and fir needles though it is not as common as the other two mites. Fir needles may be found which harbor two mites, each keeping to its own side of the midrib. It is possible that the mites *Steganacarus striculus diaphanus* and *Phthiracarus compressus* (*2*) similarly develop in spruce and fir leaves,

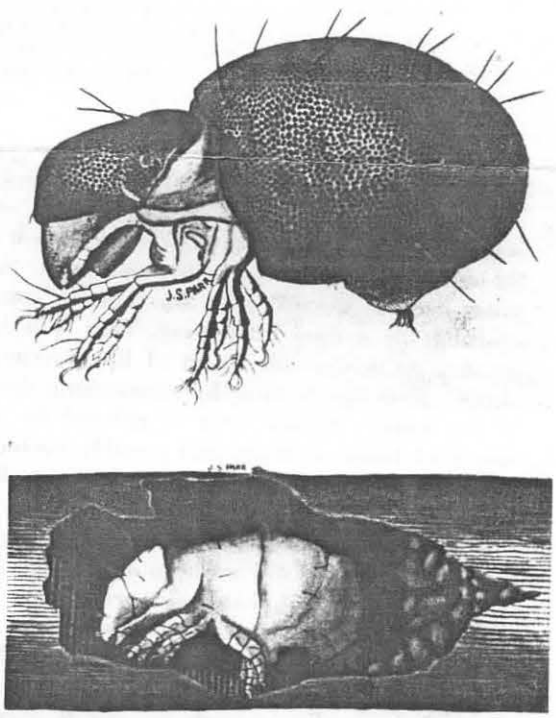

Fig. 1.—*Hoplophorella thoreaui*. (Upper) Adult. Much enlarged (natural size about 1/50 inch). (Lower) Nymph II, in spruce leaf (broken open).

[1]Determined by Alma M. Waterman through Dr. Perley Spaulding, of the Division of Forest Pathology.

but they were not common enough in the needles examined to be able certainly to identify them in the immature stages.

The midge larvae (Sciara) are not as common as are the mites and they are usually found in needles which are much more decayed (by fungi). It is not certain if the egg is deposited in leaves containing mite faeces which the midge larva then feeds on, or whether the larva feeds on undisturbed tissue. It is often found in a leaf with one or two saprophagous mites or their faeces. From needles of a sample taken July 26th were obtained full grown larvae, pupae, and leaves from which the adult had already escaped. The leaves in which these larvae were found (on July 26th) were much more decayed, softer, flabbier (flaccid), paler, than those which harbored the mites. In other words, by the time Sciara transforms to adult, its leaves are much more reduced (decomposed) than are the leaves of the mites when they transform to adults. Thus there is reason to believe that the midge feeds on the faeces of the mites, further reducing them to a fine granular substance which would be much more easily washed into the soil by percolating rainwater.

All three of the mites are to be found in the needles from spring to autumn, their adults being common in litter samples all year. The fly larvae emerge as adults near the end of July, so they may have a second brood which may overwinter as eggs. Other mites were found in the needles but they may have entered them through exit holes to eat the faeces.

Nematodes as long as half the width of the leaf (fir) occur not infrequently. One fir leaf taken May 19th contained several such nematodes among Phthiracarid faeces.

Both the mites and the midge leave their cradle with the epidermis almost intact. Similarly the above noted fungi leave the epidermis wrapped about the few internal fibers. The further reduction of these fibers, the faeces, and the epidermal envelopes, forms an unopened chapter in the story of reduction.

As these animals begin only when the needles are partly softened, they are not found in the uppermost leaves of the litter and are irregularly distributed below them so that it is difficult to estimate the percent of needles which they reduce as compared to reduction by the fungi. Moreover the efficacy of the endophages will vary widely in each locality and condition of the forest floor depending on the number of species of endophages present, the moisture, the degree of shade, degree of trampling, and related factors. Since they spend their entire cycle in the litter layer, a forest fire would wipe them out. Then when the new stand begins growing on the old burn, the mites might not come into the stand for several years,—thus accounting for the local distribution of some of these species, and possibly for differences in the rate or course of spruce-fir litter reduction.

Summary

Spruce and fir litter of northern spruce woods was found to be reduced by the immature stages of three species of saprophagous mites which eat the needles from the inside. Due to overlapping of generations, these mites feed throughout the growing season in leaves which have been softened by fungal action. A species of midge (Sciara) was also found within the needles but there is evidence that it may be a secondary saprophyte. Nothing is at present known of the ectophages of spruce and fir needles.

Literature Cited

1. Darker, G. D. 1932. The Hypodermataceae of conifers. Contrib. Arnold Arboretum No. 1.
2. Jacot, A. P. 1938. More box-mites of the Northeastern United States. Jour. N. Y. Entomol. Soc. 46:109-145.
3. ———. 1938. Four new Arthropods from New England. Amer. Midland Nat. 20: 571-574.
4. Westveld, M. 1931. Reproduction on pulpwood lands in the Northeast. U. S. Dept. Agric. Tech. Bull. 223. 52 pp.